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THE CANNONBALL MARINE MEMBER OF THE LANCE FORMATION OF NORTH AND SOUTH DAKOTA AND ITS BEARING ON THE LANCE-LARAMIE PROBLEM[1]

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Field examination by the writers and the paleontological determinations by Drs. Stanton and Knowlton during the years 1912 and 1913 show that in a large region west of Missouri River in North and South Dakota the Lance formation consists of two distinct parts, a lower non-marine part containing a flora very similar to, if not identical with, that of the Fort Union and an upper marine member containing a fauna closely resembling, but not identical with, that of the Fox Hills sandstone. This upper part, on account of its peculiar fauna, has been mapped separately and named the Cannonball marine member of the Lance formation. Farther west non-marine beds bearing lignite and occupying a similar stratigraphic position have been named the Ludlow lignitic member of the Lance.

The area examined by the writers embraces a territory of over 5,000 square miles, extending from Mandan, North Dakota, west to Montana, a distance of about 175 miles (Fig. 1), and south beyond the boundary line of South Dakota. The marine member of the Lance has been mapped from Mandan to a point 4 miles west of Haley, North Dakota, a total distance of about 130 miles. A large part of the area examined by the writers has been described already from an economic standpoint.[2]

The Lance formation had previously been mapped in two adjoining regions, the Bismark Quadrangle[3] and the Standing Rock

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[1] Published by permission of the Director of the U.S. Geological Survey.

[2] E. Russell Lloyd, "The Cannonball River Lignite Field, Morton, Adams, and Hettinger Counties, North Dakota," *U.S. Geol. Survey Bull. 541–g;* D. E. Winchester, C. J. Hares, E. M. Parks, and E. Russell Lloyd, "The Lignite Field of Northwestern South Dakota," *U.S. Geol. Survey Bull.* (in course of preparation); C. J. Hares, "Lignite in Southwest North Dakota," *U.S. Geol. Survey Bull.* (in course of preparation).

[3] A. G. Leonard, *U.S. Geol. Survey Geol. Atlas,* Bismarck Folio (No. 181), 1912.

Indian Reservation,[1] in both of which one of the writers (Lloyd) has been able to distinguish the upper marine member. Parts of these areas are included in the accompanying map (Fig. 1).

Throughout the greater part of the area studied by the writers the strata are nearly flat-lying, with only a very low general dip, usually less than 30 feet per mile, to the north or northeast. Practically the entire area is grass-covered and only in the bluffs of the larger streams and locally in high steep-sided buttes are natural rock exposures found. The relief is very slight; hence there is considerable difficulty in tracing the formation boundaries.

The general character and relations of the Cretaceous and Tertiary formations exposed in this part of the Dakotas are shown in Table I. The areal distribution is shown on the map (Fig. 1).

TABLE I

CRETACEOUS AND TERTIARY FORMATIONS IN WESTERN NORTH AND SOUTH DAKOTA

System	Series	Formation	Character	Thickness in Feet
Tertiary	Oligocene	White River	Cross-bedded sandstone and fresh-water limestone	140
Unconformity, angular up to 20° and erosional up to 1,500 feet				
Tertiary	Eocene	Fort Union	Yellow sandstone, shale, clay, and lignite	1,025
Tertiary?	Eocene?	Lance	Cannonball marine member. Dark sandy shale, dark shaly sandstone, and yellow sandstone, containing marine shells	0–300
			Ludlow lignitic member. Light sandy shale, calcareous sandstone and lignite	0–350
			Somber-colored shale, yellow sandstone, and thin lignite beds	400–525
Cretaceous	Upper Cretaceous	Fox Hills	Sandstone, yellow	25–400
		Pierre	Dark marine shale	300+

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[1] W. R. Calvert and Others, "Geology of the Standing Rock and Cheyenne River Indian Reservations, North and South Dakota," *U.S. Geol. Survey Bull. 575*, 1914.

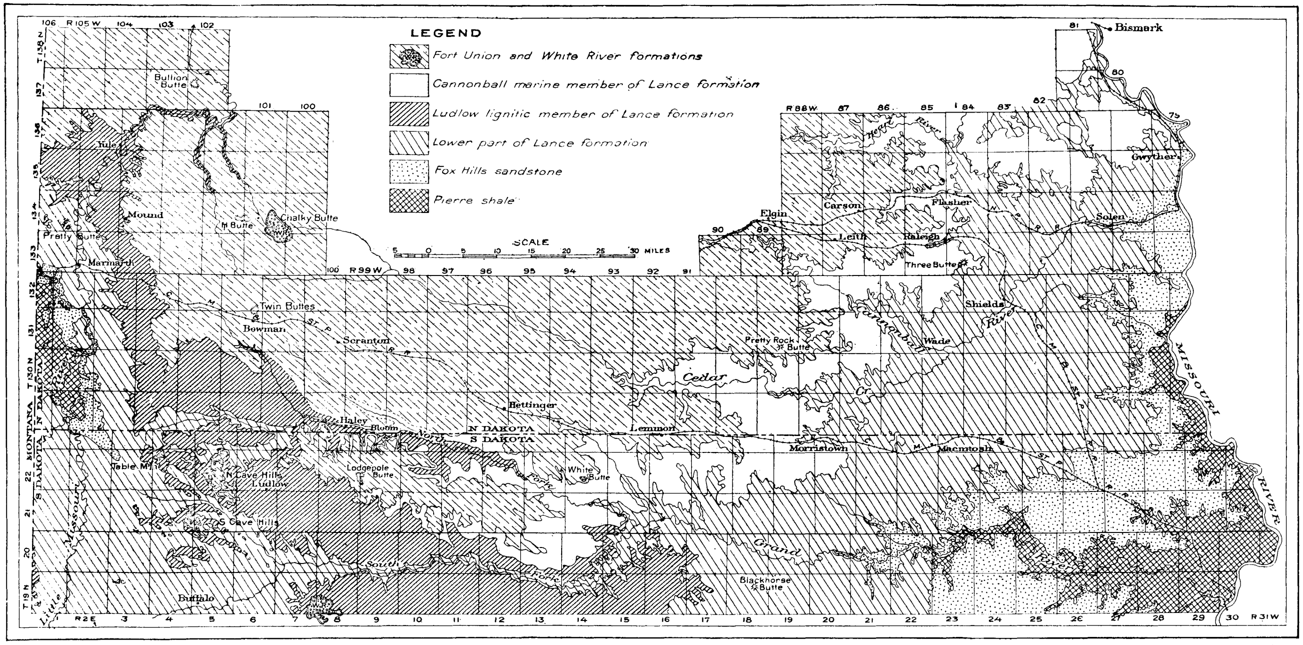

FIG. 1.—Geologic map of part of western North and South Dakota. Compiled by E. Russell Lloyd and C. J. Hares.

CRETACEOUS SYSTEM

FOX HILLS SANDSTONE

The type locality of the Fox Hills sandstone is Fox Ridge in the Cheyenne River Indian Reservation in South Dakota between Moreau and Cheyenne rivers and about 25 miles northwest of the mouth of the latter stream.[1] This region was examined in detail by V. H. Barnett in 1909, and the formation was mapped by Barnett and other geologists of the U.S. Geological Survey northward to Cannonball River.[2] The Fox Hills is made up of massive gray, yellow, and buff sandstone and banded shale, the maximum thickness in the Standing Rock and Cheyenne River Indian reservations being 400 feet and the average about 150 feet. Around the southern end of the Glendive anticline in Billings and Bowman counties, North Dakota, the Fox Hills sandstone is about 75 feet thick. It has been shown that in some localities in the Dakotas and eastern Montana[3] the overlying Lance formation is unconformable on the Fox Hills, the contact between the two being marked by erosion channels in the Fox Hills sandstone. In one locality in the Standing Rock Reservation the Fox Hills is 25 feet or less in thickness, so that either the erosion interval represented is of considerable magnitude or else the formation is peculiarly variable in thickness. This evidence of unconformity is, however, vitiated by the presence in the Standing Rock Reservation of a bed above the line of unconformity containing brackish water and marine fossils and along Little Missouri River by the gradation by alternation of beds of Fox Hills character with those of Lance character. The evidence both for and against the supposition of an unconformity of major importance at this horizon is fully discussed in the papers cited. From the stratigraphic standpoint it appears to the writers that the local unconformities that have been observed are such as would be expected where a marine formation is succeeded by one of continental origin.

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[1] The name was first used by Meek and Hayden, *Acad. Nat. Sci. Philadelphia, Proc.*, XIII (1862) 419.

[2] W. R. Calvert and Others, *op. cit.*; T. W. Stanton, "Fox Hills Sandstone and Lance Formation ('Ceratops Beds') in South Dakota, North Dakota, and Eastern Wyoming," *Am. Jour. Sci.*, 4th ser., XXX (1910) 172, 188; F. H. Knowlton, "Further Data on the Stratigraphic Position of the Lance Formation ('Ceratops Beds')"; *Jour. Geol.* XIX (1911) 358–74.

[3] F. H. Knowlton, *op. cit.*

A significant feature of the Fox Hills sandstone and underlying Pierre shale in the Standing Rock and Cheyenne River Indian reservations is that the fauna found in the sandstone cannot be distinguished from that found in the upper part of the shale, so that the strata from which the Fox Hills fauna was collected include not only the Fox Hills sandstone but also about 200 feet of the underlying Pierre shale.

TERTIARY? SYSTEM

LANCE FORMATION

Lower part.—It has been previously stated that the Lance formation in this region consists of three parts, a lower group of shale and sandstone beds of continental origin and two contemporaneous upper members, one of sandstone and shale of marine origin, the other of sandstone, shale, and lignite of non-marine origin. The lower part of the formation outcrops in a wide belt of country in Morton County, North Dakota. Northward it passes below the flood plain of Missouri River a few miles below Bismarck, and to the west it has been mapped to and beyond the Montana-Dakota state line. It occupies a large area in Bowman and Billings counties in southwest North Dakota and in adjacent parts of Montana. Throughout this whole region it is essentially uniform in character, consisting predominantly of somber-colored arenaceous shale intercalated with lenticular beds of brown or buff sandstone. Beds of brown carbonaceous shale, bog iron ore, and thin lignite are conspicuous in most outcrops. All the strata of the lower part of the Lance are lenticular in character, and a section exposed at one locality is different in most of its details from one even a short distance away. Cross-bedding is common, especially in the sandstone. Irregularity of deposition is characteristic. Near Solen on Cannonball River, 9 miles above its mouth, the lower part of the Lance has a thickness of approximately 400 feet and on Little Missouri a thickness of about 525 feet.

The fossils found in the lower part of the Lance in the western Dakotas consist of plant impressions and bones of reptiles. The plant remains are not abundant, but a few good collections have been made from widely separated localities. All of the species belong to the widespread Fort Union flora. The vertebrates include turtles and several genera of dinosaurs, among which is the large-horned Triceratops, which is diagnostic of the Lance formation. The Ceratopsian remains are especially abundant near the base of the formation in the Standing Rock Indian Reservation, but on Little Missouri River several specimens of Triceratops have been found near the top of the formation and stratigraphically below the *Ostrea glabra* zone.

Ludlow lignitic member.—The Ludlow lignitic member of the Lance formation occupies a large area in Harding County, South Dakota, and has been mapped northward into Bowman and Billings counties, North Dakota, and eastward into Perkins County, South Dakota, where it merges with the Cannonball marine member. In the vicinity of Ludlow, South Dakota, its type locality, it consists of 350 feet of loosely consolidated buff and cream-colored calcareous sandstone and shale with interbedded lignite. It contains most of the lignite of South Dakota and the presence of this lignite is one of the chief criteria for considering it a distinct member of the Lance formation. Its lithologic character in South Dakota is very like, and its fossil flora so far as determined is identical with, the Fort Union. Its flora is like that of the lower part of the Lance, but its lithology is quite different. On the other hand, in North Dakota its flora has the same affinities as in South Dakota, but lithologically it resembles the lower part of the Lance, except for the presence of the numerous lignite beds. It is this variation in color and lithology of the Lance that renders its separation from the overlying Fort Union so difficult.

The following sections show the lithologic character of the Ludlow lignitic member.

COMPOSITE SECTION IN SECS. 32 AND 36, TP. 22 N., R. 5 E., BLACK HILLS MERIDIAN, SOUTH DAKOTA

	Ft.	In.
Fort Union formation		
Sandstone, yellowish, and shale	255	0
Ludlow lignitic member of the Lance formation		
Lignite		8
Sandstone, somewhat shaly	45	0
Shale, dark	2	0
Lignite	2	4
Sandstone, light colored, grayish, argillaceous	12	0
Sandstone, buff, with ferruginous specks	15	0
Lignite		2
Sandstone, buff, fine-grained, muscovitic	11	0
Liginite		3
Sandstone	8	0
Lignite		6
Sandstone, buff	25	0
Shale, bluish	1	0
Shale, carbonaceous		10
Shale, arenaceous	5	0
Lignite		1
Sandstone, buff, soft	5	4
Sandstone	1	0
Shale, arenaceous with carbonaceous streaks	4	0
Sandstone, argillaceous	6	0
Lignite	1	0
Concealed interval	22	0
Sandstone, drab, cross-bedded, ripple-marked	3	0
Shale, arenaceous	4	0
Lignite	1	5
Shale, brown	3	0
Lignite	2	1
Shale, dark		5
Lignite		8
Shale	1	3
Lignite	1	5
Shale, brown	4	0
Lignite	2	3
	446	8

PARTIAL COMPOSITE SECTION, TP. 20 N., R. 9 E., BLACK HILLS MERIDIAN, SOUTH DAKOTA

	Ft.	In.
Ludlow lignitic number of the Lance formation		
Sandstone, yellow, medium fine-grained, capping hills	20	0
Shale, brown	3	0
Lignite	1	0
Shale, brown		6
Sandstone, yellow	16	0
Shale, brown	1	10
Lignite, dirty		8
Shale, brown	3	0
Shale, black		8
Lignite, dirty		6
Shale, brown	1	6
Sandstone, buff to yellow	12	0
Shale, brown	2	0
Shale, black		4
Lignite, fair		8
Sandstone and shale, with lignite streaks	13	6
Lignite, fair		8
Shale		3
Lignite, good	3	6
Shale, brown, arenaceous	1	0
Sandstone		
	82	7

COMPOSITE SECTION IN TP. 21 N., R. 7 E., BLACK HILLS MERIDIAN, SOUTH DAKOTA

	Ft.	In.
Fort Union formation		
Sandstone and shale	138	0
Ludlow lignitic member of the Lance formation		
Shale, chocolate-colored	2	0
Sandstone, buff, yellow, fine-grained, alternating with buff shale	9	0
Shale, chocolate-colored	3	4
Lignite	1	0
Shale, buff and yellow sandstone, alternating	16	0
Shale, chocolate-colored	3	0
Sandstone, brown, fine-grained	2	6
Shale	10	0
Lignite, Gianniatti bed	11	8
Sandstone, light, argillaceous	16	4

	Ft.	In.
Shale, brown	3	0
Lignite	4	2
Shale	13	0
Lignite	3	8
Shale and sandstone	15	0
Lignite, poor	3	4
Shale, carbonaceous		6
Shale		
	255	6

SECTION ON WEST SIDE OF LITTLE MISSOURI RIVER, SEC. 10, TP. 135 N., R. 105 W., NORTH DAKOTA[1]

	Ft.	In
Fort Union Formation		
Sandstone, light	15	2
Ludlow lignitic member of Lance formation		
Shale, dark	24	0
Limestone, arenaceous	2	10
Shale, blue	7	2
Sandstone, gray, friable	4	0
Shale, gray	3	7
Sandstone, argillaceous	1	4
Shale, drab, hard	1	2
Lignite	4	5
Shale, dark, hard	2	10
Shale, light, fossils, leaves	2	10
Lignite	2	6
Shale, carbonaceous	1	8
Sandstone	2	8
Shale	1	8
Sandstone and shale, alternately	2	8
Lignite	1	0
Sandstone and shale	3	0
Lignite		6
Sandstone	4	0
Lignite	1	7
Sandstone, white, hard	3	0
Sandstone in upper part, shale in lower part; *Ostrea glabra* above base (only representative found of Cannonball marine member)	33	11

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[1] See footnote, p. 533.

	Ft.	In.
Lignite	1	11
Sandstone and shale, sandstone in upper part and shale below	27	0
Lignite		10
Shale	11	0
Lignite	3	0
Shale	3	4
Sandstone, hard ledge in upper part	13	2
Lignite	5	3
Shale	1	8
Lignite	1	2
Shale	1	4
Lignite	5	0
Shale	8	6
Lignite	6	11
Shale	4	8
Lignite		6
Shale	7	6
Lignite	5	4
Sandstone	15	4
Shale		
	250	11

SECTION ALONG NORTH FORK OF GRAND RIVER AT BLOOM, SOUTH DAKOTA[1]

	Ft.	In.
Fort Union formation(?)		
1. Sandstone, brown and yellow, fine-grained, thin-bedded, interbedded with lenses of compact, bluish-gray limestone		
Cannonball marine member of the Lance formation		
2. Sandstone, dark gray, very calcareous, marine fossils *Nucula* sp., *Callista deweyi*, *Pholas* sp., *Corbula* sp., *Anchura americana*	10	0
Ludlow lignitic member of the Lance formation		
3. Lignite	2	0
4. Shale and sandstone, interbedded	40	0
5. Lignite	1	0
	53	0

NOTE.—No. 1 was considered as Fort Union but very possibly is Cannonball, as indicated by more recent field work in other parts of the field.

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[1] See footnote, p. 533.

GENERALIZED SECTION ALONG NORTH FORK OF GRAND RIVER BETWEEN BLOOM, SOUTH DAKOTA, AND HALEY, NORTH DAKOTA[1]

	Ft.	In.
1. Sandstone, brown and yellow, fine-grained, thin-bedded, and lenses of limestone	30	0
2. Sandstone, marine; burrows of a Teredo-like shell, *Anchura americana*	10	0
3. Shale	1	0
4. Lignite	2	0
5. Shale and sandstone, interbedded. Sandstone in lower part, light brown, medium fine-grained, micaceous; containing *Halymenites major*, *Thracia* sp., *Nucula* sp., *Callista* sp., *Pholas* sp., imprints of pelecypods and shark teeth	40	0
6. Lignite	1	0
7. Shale	4	0
8. Lignite	2	3
9. Shale		
	90	3

NOTE.—No. 1 was considered Fort Union but may be Cannonball; Nos. 2 and part of 5 are marine, and Nos. 3, 4, 6, 7, 8, and 9 are considered fresh-water.

Cannonball marine member.—The Cannonball marine member of the Lance formation has been traced and mapped in an area extending from near Mandan, North Dakota, to the vicinity of Ralph post-office in Harding County, South Dakota, and 4 miles west of Haley, Bowman County, North Dakota. The presence of brackish-water fossils, *Ostrea glabra*, near Yule on Little Missouri River in Billings County, North Dakota, shows that the sea probably extended some distance farther to the west than its sediments have been mapped. The extent of this member east of Missouri River is unknown.

The marine member is composed predominantly of dark sandy shale or shaly sandstone with a subordinate amount of dark-yellow and gray sandstone. It also contains some thin limestones. All the strata are lenticular in character and individual beds can be followed for only short distances. The member is typically exposed in the bluffs of Cannonball River in Tps. 132 and 133 N., Rs. 87 and 88 W. The following sections measured in the type area show the character of the strata of the Cannonball marine member and of the strata which underlie and overlie it.

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[1] The last three sections expose the interrelations of the Ludlow lignitic and the Cannonball marine members.

Section near Base of the Cannonball Marine Member, in South Bluff of Cannonball River, Sec. 33, Tp. 132 N., R. 87 W.

	Ft.	In.
1. Sandstone and sandy shale, yellowish gray	23	0
2. Sandstone, yellowish gray, unconsolidated, with thin lenses of shale near the bottom, containing poorly preserved leaf impressions	22	0
3. Shale, brown, sandy	22	0
4. Shale, bluish brown	2	0
5. Lignite		4
6. Shale, bluish brown	4	0
7. Sandstone, gray, unconsolidated	45+	0
8. Concealed to river level	15	0
	133	4+

In this section no definite line could be drawn between the lower part of the Lance and the Cannonball member. No. 1 and probably No. 2 belong to the marine member.

Section in South Bluff of Cannonball River, about Three-fourths of a Mile West of Foregoing Section

	Ft.	In.
1. Sandstone, yellow	25	0
2. Shale, containing poorly preserved plant remains	4	0
3. Sandstone, gray		
	29	0

The sandstone No. 1 in this section appears to be unconformable on the shale. It is probably the lowest bed of the Cannonball member.

Section in Bluffs of Cannonball River, near Janesburg, North Dakota, Tp. 132 N., R. 88 W.

	Ft.	In.
1. Sandstone, fine-grained, containing "cannonball" concretions	40±	0
2. Shale, dark, sandy	10	0
3. Sandstone and sandy shale, light colored, with "cannonball" concretions	21	6
4. Shale, dark, sandy, with *Perna* n.sp.	4	0

	Ft.	In.
5. Sandstone and shale, light colored, thin-bedded, the shale containing indeterminable vegetable remains	30	0
6. Sandstone, consolidated	1	6
7. Shale, light blue	1	6
8. Sandstone and shale, alternating	15	0
9. Shale, dark, carbonaceous	1	0
10. Sandstone and shale, alternating, base concealed by talus at base of slope	5+	
	129	6+

No. 4 and the overlying beds of this section are undoubtedly of marine origin; the lowest beds may be non-marine but no definite line could be drawn.

Section of Part of Cannonball Marine Member in South Bluffs of Cannonball River, E. ½ Sec. 5, Tp. 132 N., R. 88 W.

	Ft.	In.
Shale, sandy, black and brown, with *Pyrifusus newberryi* (?), fragments of *Crassitellites*, and a coral belonging to an undetermined genus	16	6
Sandstone, yellow, largely consolidated, but with lenticular concretions of hard sandstone	31	6
Shale, sandy, dark gray, nearly black	52	0
	100	0

Section of Lower Part of Fort Union Formation and Upper Part of Cannonball Marine Member of Lance Formation in South Bluff of Cannonball River, Secs. 31 and 32, Tp. 133 N., R. 88 W.

	Ft.	In.
Sandstone, yellow. Upper part massive, lower part thin-bedded and near base interbedded with thin bands of gray shale	30	6
Sandstone, dark gray to black	3	6
Sandstone, yellow, thin-bedded, interbedded with gray shale	13	6
Sandstone, gray, concretionary		6
Shale, bluish gray and somber-sandy	52	0
Shale, dark gray	54	6
Sandstone, yellowish gray, unconsolidated	5	0
Sandstone, yellow, hard at top, containing *Lunatia concinna*, *Turris minor*, *Fasciolaria buccinoides*, *Pyrifusus* sp., *Anchura* sp., and an undescribed coral	6	0
Shale, sandy, dark gray, grading at top into sandstone	31	6
	197	0

The upper sandstone of this section probably belongs to the Fort Union formation and the remainder to the Cannonball member of the Lance formation.

Sections similar in general character to those given above are exposed in the bluffs of Heart River and on Cedar Creek. The general appearance of the more sandy rocks is very much like that of the Fox Hills sandstone. The shale is very much like the Pierre.

A peculiar feature of both the Fox Hills sandstone and the Cannonball member of the Lance is the abundance of round concretions commonly known as "cannonballs." They are formed by cementation of the sandy shale by the deposition of calcium carbonate. These are true septarian nodules with radiating and concentric veins of calcite. The best examples observed are in a railway cut a few miles west of Raleigh, North Dakota. Where the "cannonballs" are exposed by stream erosion they are mostly weathered and broken to pieces.

The rocks of the Cannonball member weather typically into rounded hills, and in the interstream areas natural rock exposures are very few. In a large part of the area where the member was examined in South Dakota the only evidence that the beds are of marine origin are a few thin beds of nodular fossiliferous limestone, the presence of which is shown by the lines of residual bowlders at the borders of level-topped hills. The topography is such, however, that these horizons can be followed for long distances. No definite line could be drawn in the field between the Cannonball marine member and the lower part of the Lance. The contact of the two groups of strata is exposed at only a few places and in all such cases it seems to be impossible to tell where the beds of non-marine origin stop and those of marine origin begin. It follows from the foregoing statement that there is no evidence of unconformity at this horizon.

The relationship of the Cannonball member with the underlying lower part of the Lance is well shown in the region northwest of Solen on Cannonball River, North Dakota. In this area the characteristic chaos of badlands, formed by the erosion of the sandstone and shale of the lower part of the Lance, is bordered on the north by a high, nearly level plateau which is capped by the lower fossiliferous sandstone of the Cannonball member. The top of the plateau is approximately 500 feet above and only about 2 miles distant from the river. The characteristic badland-forming strata of the lower part of the Lance extend up to within about 100 feet of the top of the plateau but here, as elsewhere, no sharp line of demarkation can be drawn.

Dr. Stanton has kindly prepared the following statement concerning the fauna of the Cannonball member.

The fauna of the Cannonball marine member of the Lance may now be characterized as a modified Fox Hills fauna. It contains a considerable proportion of undescribed species of Cretaceous affinities, and it is noteworthy that a number of the most common Fox Hills species have not been discovered in this fauna. The list of forms recognized is as follows:

Nodosaria sp.
Caryophyllia ? sp.
Anomia sp.
Perna sp.
Crenella sp.
*Cucullaea shumardi M. and H.
†Glycimeris subimbricata (M. and H.)
*Leda (Yoldia) scitula M. and H.
*Leda equilateralis M. and H. ?
*Nucula planimarginata M. and H.
‡Crassatellites evansi (H. and M.)
Solemya ? sp.
*‡Lucina occidentalis (Morton)
Corbicula cytheriformis M. and H.
†Cyprina ovata M. and H.
*Cyprina ovata var. compressa M. and H. ?
Veniella ? sp.
Callista sp. *a*
Callista sp. *b*
Tellina ? sp.
Thracia sp. related to T. subgracilis Whitfield
†Teredo globosa M. and H.
†Teredo selliformis M. and H.
Corbula sp.
Entalis sp.
Scala ? sp.
Turritella ? sp.
‡*Lunatia concinna (H. and M.)
Cerithium ? sp.
‡*Anchura americana (E. and S.)
Anchura americana (E. and S.) robust variety
Helicaulax ? sp.
†*Cantharus (Cantharulus) vaughani M. and H.
*Pyrifusus (Neptunella) newberryi M. and H. ?
*Fasciolaria buccinoides M. and H.
*Fasciolaria (Piestochilus) culbertsoni M. and H.
*Turris contortus M. and H.
Turris sp. related to T. contortus M. and H.
*Turris minor (E. and S.) ?
Cinulia sp.
*Cylichna scitula M. and H. ?

In this list of about 40 forms there are 21 named species and varieties of which 15 (marked *) occur in the Fox Hills, 4 (marked ‡) occur in the Pierre, and 5 (marked †) were originally described from rocks now known to belong to the marine member of the Lance. One species, *Corbicula cytheriformis*, was described from the Judith River formation and is known in the Mesaverde formation and the Lance of other areas. The fossil seaweed, *Halymenites major*, which is common in the Fox Hills and other sandy formations of the marine Cretaceous, is also associated with the above listed fauna.

FORT UNION FORMATION

West of Missouri River Fort Union formation overlies the Cannonball member of the Lance and on Little Missouri it overlies the Ludlow lignitic member of the Lance. In this part of the Dakotas a large part of the formation has been removed by erosion, but in Billings County, North Dakota, one of the writers (Hares) has found a thickness of 1,025 feet. The formation consists of calcareous sandstone and shale of continental origin, containing numerous thick persistent beds of lignite and an abundant flora and fresh-water invertebrate fauna. Some of the thick lignite beds have burned extensively, and great numbers of red hills composed of fused and baked rock are characteristic features of the formation. The lower 100 feet of the formation is made up almost wholly of partially consolidated yellow and gray fine-grained sandstone which is in some localities indistinguishable from the sandstone at the top of the Cannonball member. At numerous other exposures, however, where the upper bed of the Cannonball member is a sandy shale, the contact is easily followed. At one locality on the north bank of Heart River in Tp. 136 N., R. 88 W., there is an erosion channel from 30 to 50 feet deep in the Cannonball member filled with the channel deposits of a Fort Union stream. Similar channel sandstones at the base of the Fort Union were seen along Little Missouri, near Yule, and at the mouth of Deep Creek, and also on Sand Creek, in Billings County, North Dakota. These strata show evidence of a rapid change in the character of the sedimentation. They consist predominantly of coarse sandstone containing lenses or pockets of conglomerate and of soft clay shale. The conglomerate consists of pebbles derived from the strata of the surrounding region and contain numerous waterworn bones, teeth, fish scales, fragments of silicified wood, and lignite in the form of tree trunks. Among the vertebrate remains are two mammalian teeth which have been identified by Dr. J. W. Gidley of the U.S. National Museum as *Euprotogonia* sp., second lower molar of left jaw, and *Pantolamda cavirictus*, upper premolar. Both of these species are found in the Fort Union beds of Sweetgrass

County, Montana. The remaining fragments are identified as representing *Champsosaurus*, a crocodile, a turtle, and *Lepisosteus*.

Lenses of conglomerate similar to the one described above were seen at other localities near the base of the Fort Union along Heart River, and in one exposure a bed of conglomerate a few inches thick forms the base of the formation. Along Little Missouri in sec. 31, Tp. 138 N., R. 102 W., a conglomerate at the base of the Fort Union contains bowlders up to a foot in diameter. The unconformity shown in these exposures is such as would be expected in a transition from marine to continental sedimentation.

ROCKS OF POST-FORT UNION AGE

The rocks of post-Fort Union age in this region embrace: (1) small remnants of sandstone, marl, and limestone of the White River formation on the tops of a few high buttes; (2) sand and gravel beds on the tops of high buttes, probably deposited by streams previous to the present cycle of erosion and derived in part from the White River formation; (3) terrace gravel in the valleys of the larger streams from 50 to 250 feet above the present valley floors; and (4) a large number of scattered glacial bowlders, the remnants of the drift of one of the earlier glacial epochs. These later rocks occupy small areas and are not shown on the accompanying map.

INTERRELATIONSHIPS OF THE LUDLOW LIGNITIC AND THE CANNONBALL MARINE MEMBERS OF THE LANCE FORMATION

It has been shown that the Lance formation in a large region immediately west of Missouri River consists of two parts, the upper of which, the Cannonball member, is marine and contains a fauna similar to, but not identical with, that of the Fox Hills sandstone. The Cannonball member becomes gradually thinner toward the west, and the sea in which it was deposited perhaps did not extend as far west as the Montana line. The oyster beds near Yule in Billings County, North Dakota, first discovered by Leonard and later described by Stanton,[1] may represent the western-most limit to which the Cannonball sea extended. This region was studied in 1911, and it was found by Hares that the beds containing the oysters are about 700 feet above the base of the Lance.

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[1] T. W. Stanton, "The Age and Stratigraphic Relations of the 'Ceratops Beds' of Wyoming and Montana," *Washington Acad. Sci., Proc.*, XI, (1909), 249; "Fox Hills Sandstone and Lance Formation ('Ceratops Beds') in South Dakota and Eastern Wyoming, *Am. Jour. Sci.*, 4th ser., XXX (1910), 183–84.

The zone in which *Ostrea glabra* and *Ostrea subtrigonalis* occur, in Tps. 136, 134, and 134 N., R. 105 W., is considered the westward extension (so far as known at present) of the strata of marine origin, as the oysters are brackish-water animals and consequently must have had some connection with the open sea. The most westerly collection of the Cannonball marine fauna is only 30 miles east of this place, in sec. 21, Tp. 129 N., R. 100 W., 4 miles west of Haley, and occurs stratigraphically within 100 feet of the T Cross lignite bed which was traced from Tp. 134 N., R. 105 W., to the west side of Tp. 129 N., R. 101 W. The oysters occur about 70 feet above the same lignite bed; it is assumed that the seaward connection was to the east. The oysters also occur about 120 feet below the base of the Fort Union formation which in the Little Missouri region has the same characteristics (channel conglomerate, light-yellow, somewhat massive sandstone) as it does in the Cannonball River country where it rests directly on the Cannonball marine member. It appears that the sea in which were deposited some 300 feet of marine sediments transgressed westward across the lignitic strata of the Ludlow member and that the position of its westward limit is underneath the divide between the drainage of Little Missouri and that of Grand and Cannonball rivers. All of the Triceratops collected in the Little Missouri country came from below the T Cross lignite bed and the oysters from above it. Calvert, however, states that in Montana "Ceratopsian bones were found just above the lowest persistent lignite bed, but there is certainly nothing in the character of the overlying strata to suggest that similar bones do not occur therein up through a stratigraphic distance of perhaps 500 feet."[1] The T Cross lignite bed was mapped to the Montana state line and it is undoubtedly the same lignite as the "persistent lignite" referred to above.

The presence of numerous lignite beds in the upper part of the Ludlow lignitic member of the Lance is in strong contrast to the undifferentiated lower part of the formation, and the absence of marine fossils in this member is in contrast to the Cannonball marine member. The Ludlow lignitic and the Cannonball marine members are considered to be contemporaneous in age.

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[1] W. R. Calvert and Others, "Lignite in Eastern Montana," *U.S. Geol. Survey Bull. 471*, p. 197, 1912.

RELATIONSHIPS IN OTHER AREAS

The Cannonball sea presumably advanced into western North and South Dakota from the east or northeast, and by inference the Cannonball member continued with undiminished or with increased thickness to the north and northeast. Practically the whole region east of Missouri River is deeply covered with a mantle of the drift of the last Wisconsin ice invasion, and the underlying formations are exposed only in isolated localities. In this region the Lance formation has been mapped about 50 miles eastward from Bismark but is presumably unrecognizable farther northeast.[1] It seems a very reasonable supposition that the lower fresh-water part of the Lance may not extend very far to the east and that where it is absent marine sedimentation was continuous throughout the time when the fresh-water Lance was being deposited elsewhere.

Beyond the limits of Cannonball marine sedimentation on the west the Fort Union formation rests directly on the fresh-water beds of the Lance, and, except along the badlands of Little Missouri, no definite line of demarkation between the two has been drawn. In general the Lance is distinguished lithologically by a greater proportion of somber-colored shale and sandstone, the large number of the bog iron ore nodules and layers, by irregularity of deposition, and by a paucity of lignite. The Fort Union, on the other hand, contains a larger proportion of yellow and white sandstone, quartzite, and thin limestone, and almost everywhere contains a large number of lignite beds, some of which are very thick and persistent. The rocks of this formation are fine-grained and regularly bedded and give rise to angular topographic forms. In a large area in eastern Montana, mapped by the U.S. Geological Survey in 1910, it was found that the color change from somber below to yellow above does not take place everywhere at the same horizon. One example is cited by Calvert[1] where in 2 miles the somber beds transgress a distance of 200 feet upward into the yellow.

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[1] A. G. Leonard, "The Geological Map of North Dakota," *Quar. Jour. Univ. N.Dak.*, IV (1913), 4.

At present the only accepted criterion for the distinction of the Lance formation from the Fort Union in areas where the Lebo andesitic member of the Fort Union[2] and the Cannonball marine member of the Lance are absent is the presence in the former of Triceratops and its associated fauna. On the basis of its fauna and flora the Lance formation is approximately correlated with the Denver and Arapahoe formations of the Denver Basin, Colorado,[3] and with a part of the "Upper Laramie" described by Veatch[4] in Carbon County, Wyoming. In both these regions the supposed Lance equivalents usually rest unconformably upon a thick series of fresh- and brackish-water beds—the Laramie of the Denver Basin and the "Lower Laramie" of Carbon County, Wyoming. Thus the correlations made on the basis of the vertebrate fauna and the flora indicate that the Laramie is older than the Lance. In the Denver Basin the Laramie rests conformably on the Fox Hills sandstone.

A comparison of the stratigraphic section in the Denver Basin and adjoining regions with that in North and South Dakota presents certain anomalies which are not easy of interpretation. Knowlton[5] has maintained that there is an unconformity throughout the northeastern Plains region between the Fox Hills sandstone and the Lance which represents the time equivalent of the whole of the Laramie of the Denver Basin as well as an unconformity above the Laramie. Numerous localities in Wyoming, Montana, and North and South Dakota are described by Knowlton where this unconformity is supposed to be shown, (1) by erosion channels in the Fox Hills sandstone; (2) by discordance of dips between the two formations; or (3) by the great variation in thickness of the Fox Hills sandstone. In each case, however, the facts can be explained on a theory of practically continuous and unequal deposition.[1] Furthermore, the presence in the Dakotas of a marine fauna very similar to that of the Fox Hills sandstone, overlying the fresh-water sediments of the Lance, renders less tenable the theory of an unconformity of any importance at the base of the Lance, since the open sea must have persisted throughout Lance time in a region not very remote from western North Dakota.

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[1] W. R. Calvert, "Geology of Certain Lignite Fields in Eastern Montana," *U.S. Geol. Survey Bull. 471*, p. 197, 1912.

[2] G. S. Rogers, "The Little Sheep Mountain Coal Field, Dawson, Custer, and Rosebud Counties, Montana," *U.S. Geol. Survey Bull. 531*, pp. 168–172, 1913.

[3] S. F. Emmons, Whitman Cross, and G. H. Eldridge, "Geology of the Denver Basin in Colorado," *U.S. Geol. Survey Mon. 27*, 1896.

[4] A. C. Veatch, "On the Origin and Definition of the Geologic Term 'Laramie,'" *Am. Jour. Sci.*, 4th ser., XXIV (1907), 18–22; *Jour. Geol.*, XV (1907), 526–49.

[5] F. H. Knowlton, "The Stratigraphic Relations and Paleontology of the 'Hell Creek Beds,' 'Ceratops Beds,' and Equivalents, and Their Reference to the Fort Union Formation," *Washington Acad. Sci., Proc.*, XI (1909), 179–238; "Further Data on the Stratigraphic Position of the Lance Formation ('Ceratops Beds')," *Jour. Geol.*, XIX (1911), 358–76.

Two other explanations have been suggested, the first that the fresh-water Lance strata of the Dakotas are the equivalents of the Laramie, Arapahoe, and Denver formations of the Denver Basin and of both the "Upper Laramie" and "Lower Laramie" of Carbon County, Wyoming. In this case the unconformity at the base of the Arapahoe is not of widespread general importance. The other and, to the mind of the writers, the more plausible hypothesis is that the Fox Hills sandstone of the Denver Basin is not the time equivalent of that in the type locality in South Dakota but is considerably older. The Fox Hills sandstone is, under this supposition, merely a near-shore phase of the sedimentation of the Montana sea. This sea persisted to much later time in the Dakotas than in Colorado, and the sedimentation was practically continuous until the close of the Fort Union. The possibility of finding a region where sedimentation was continuous throughout Laramie, Arapahoe, and Denver time was pointed out by Cross in 1909.[2] This deposition, it would seem, continued in the Dakotas in the open sea until near the close of Laramie and probably also throughout the period of erosion following the Laramie. Then the sea withdrew still farther to the east and with the beginning of Lance time continental sedimentation was inaugurated over a large part of the eastern Rocky Mountain and Great Plains region. The last advance of the sea into the region of the Dakotas was approximately contemporaneous with the final dying-out of the Cretaceous dinosaur fauna, but there was no marked break in the continuity of sedimentation until the close of the Fort Union. Then the area suffered deformation and the erosion of thousands of feet of strata before the deposition of the later formations which rest unconformably on the Fort Union and all the underlying formations.

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[1] T. W. Stanton, "Fox Hills Sandstone and Lance Formation ('Ceratops Beds') in South Dakota and Eastern Wyoming," *Am. Jour. Sci.*, 4th ser., XXX (1910), 172–88.

[2] Whitman Cross, "The Laramie Formation and the Shoshone Group," *Washington Acad. Sci., Proc.*, XI (1909), 35.

IS THE LANCE FORMATION TERTIARY OR CRETACEOUS?

In a general consideration of the age of the late Cretaceous or early Tertiary formations in the Rocky Mountain and Great Plains regions there are five lines of evidence which must be taken into consideration, and the decision at which any geologist will arrive will depend largely upon the relative importance which he gives to one or another of these lines of evidence. In a paper dealing primarily with the stratigraphy of a limited area in the Great Plains the larger and more general problem can be outlined only very briefly.

In the opinion of the writers the greatest weight should be given to the evidence of diastrophism. This, however, is of undetermined significance. The greatest break in the sedimentary record comes at the close of the Fort Union where there was everywhere, so far as known, in the Rocky Mountain and Great Plains regions an interval of long erosion and in many places of extensive folding. An earlier but apparently much less extensive break in the continuity of sedimentation is represented by erosional unconformities of greater or less extent at the base of the Raton, Dawson, Arapahoe, and "Upper Laramie" formations in New Mexico, Colorado, and Wyoming. An attempt to show that this unconformity is general throughout the northern plains region has, as previously pointed out, met with little success. In the Gulf and Atlantic Coastal Plains provinces the interval between the Cretaceous and Tertiary systems is marked by a great change in marine faunas and presumably by a profound break in the sedimentary record. Obviously, if a definite correlation can be made of this unconformity in the Coastal Plain region with an unconformity in the Rocky Mountain region a long step has been taken toward settling the problem for all of the western region.

This leads directly to a second line of evidence—the fossil flora. The recent work of F. H. Knowlton[1] and E. W. Berry has shown a close relationship between the floras of the Midway and Wilcox formations of the Gulf region, which is indisputably of age, with the floras of the Raton and the Denver formations Eocene of New Mexico and Colorado. This evidence, together with the fact that the Raton and the Denver and Arapahoe formations rest unconformably on underlying formations which contain totally different fossil floras, has led Knowlton to the conclusion that the Raton and Denver formations are of Tertiary age. This conclusion is now accepted by the U.S. Geological Survey, but some geologists question the correlation, as it depends mainly on the evidence of the fossil flora.

When we turn to the evidence gathered from a study of the marine invertebrates we arrive at a diametrically opposite conclusion. As has been pointed out in preceding pages, the marine fauna of the Lance formation is distinctly a Cretaceous fauna very closely related to the fauna of the Fox Hills sandstone. It has been pointed out too that the Lance and Fort Union formations should be grouped together both on account of the close relationship of their fossil floras and because in places no lithologic separation of the two can be made. Thus the presence of a marine Cretaceous fauna in the Lance indicates that the Lance and probably also the Fort Union should be placed in the Cretaceous system. This would make the line between the Cretaceous and Tertiary correspond with the major unconformity above the Fort Union. It must be admitted that in the Rocky Mountain and the Great Plains regions no marine fauna of undoubted Tertiary age is known with which the Lance fauna may be compared, and there is a possibility that in this area the Fox Hills marine fauna lived over from the Cretaceous into the Tertiary and thus became contemporaneous with the totally different marine faunas of the Gulf and Atlantic coasts, but if this did happen it is the first recorded case of such contemporaneous Cretaceous and Eocene faunas.

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[1] F. H. Knowlton, "Results of a Paleobotanical Study of the Coal-bearing Rocks of the Raton Mesa Region of Colorado and New Mexico," *Am. Jour. Sci.*, 4th ser., XXV (1913), 526–30.

The evidence of the reptilian fossils in the Lance formation supports the evidence of the marine fauna. This—the Triceratops fauna—is the last of the great dinosaur faunas of the Mesozoic and for that reason has been considered generally by vertebrate paleontologists as sufficient evidence of the Mesozoic age of the formation. It is, however, just as probable that the Ceratopsian dinosaurs lived over into the Tertiary as that the marine Fox Hills fauna did so.

There remains yet to be considered the evidence of the mammalian fauna of the Fort Union formation. This fauna, of course, has its closest affinities with the succeeding Eocene faunas, since practically no mammalian fauna is known in the later Cretaceous formations. There is here the possibility that the Tertiary mammalian faunas began their development before the close of the Cretaceous. Lee[1] has recently described a find of a bone of a Creodont mammal associated with Ceratopsian bones in the Dawson arkose which shows that Ceratopsian dinosaurs and mammals of Tertiary aspect must have lived at the same time.

Such in outline is the Lance problem as it stands today. A recent detailed consideration of all of the evidence has led to a decision by the U.S. Geological Survey that the Denver and Arapahoe, Dawson, and Raton formations in Colorado and New Mexico all be placed in the Tertiary system. This decision was based primarily on the correlation of these formations with the Wilcox formation of the Gulf region on the evidence of their fossil floras and also on the consequent correlation of the unconformities in the two regions. Although the Lance formation is believed to be of about the same age as the Denver, Raton, and "Upper Laramie," it is classified by the U.S. Geological Survey as Tertiary(?), the doubt being thus expressed on account of the Cretaceous character of the Cannonball marine fauna. The writers believe that greater weight should be given to the evidence of the marine faunas and the dinosaurs, and that, in view of the strong evidence presented by these faunas, the correlations made on the basis of fossil floras should not be considered as conclusive.[1]

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[1] W. T. Lee, "Recent Discovery of Dinosaurs in the Tertiary," *Am. Jour. Sci.*, 4th ser., XXXV (1913), 531–34.

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[1] This paper was submitted for publication in the *Journal of Geology* in June, 1914. Further studies on the Lance problem have strengthened the conviction of the writers that the Lance is Cretaceous.